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Economic Assessment of Enhanced Coalbed Methane Recovery for Low Rank Coal Seam

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Abstract

Enhanced Coalbed Methane Recovery (ECBMR) is usually targeted for the bituminous coals, for the methane content in such coals is rather high and it leads to the higher profit by methane sales. Generally, methane content of low rank coals is small. However, adsorption ratio of CO_2/CH_4 is high for low rank coal. It suggests that the CO_2 adsorption volume of low rank coal is large. Moreover, some low rank coal seams have high permeability. Low rank coal seams have advantage of high CO_2 adsorption volume and high permeability, and disadvantages of low methane content, possibility of large swelling from the viewpoint of ECBMR.

When the carbon credit is expected, CO_2 storage in low rank coal seams is very promising due to their high CO_2 storage capacity. At the same time we must consider negative effect of CO_2 storage on the decrease of permeability caused by large swelling (CO_2 adsorption).

A case study of economic assessment was made for low rank coal seams with sensitivity analysis. Well type of five spot patterns was employed. Well spacing, CO_2 concentration of injected gas and carbon credit is the parameter of sensitivity analysis.

The results showed CO_2 concentration was the most important factor to determine the economy of the project affecting the permeability and the CO_2 storage rate. By selecting the optimum CO_2 concentration of the injected gas, the low rank coal would be one of the options for underground CO_2 storage under certain carbon credit.

Keywords: ECBMR; Low rank coal; CO_2; Geological storage; Economic assessment

1. Introduction

Enhanced Coalbed Methane Recovery (ECBMR) is usually targeted for the bituminous coals, for the methane content in such coals is rather high and it leads to the higher profit by methane sales. Generally, methane content of low rank coals is small. However, adsorption ratio of CO_2/CH_4 is high for low rank coal. It suggests that the CO_2 adsorption volume of low rank coal is large. Moreover, some low rank coal seams have high permeability. Low rank

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When the carbon credit is expected, CO_2 storage in low rank coal seams is very promising due to their high CO_2 storage capacity. At the same time we must consider negative effect of CO_2 storage on the decrease of permeability caused by large swelling (CO_2 adsorption).

A case study of economic assessment was made for low rank coal seams with sensitivity analysis. Well type of five spot patterns was employed. Well spacing, CO_2 concentration of injected gas and carbon credit is the parameter of sensitivity analysis.

2. Setting of Conditions

We assumed two types of coal seams with different rank, bituminous coal and low rank coal (sub-bituminous coal). As the former a coal seam in North Appalachian Basin in the USA was selected, and for the latter Powder River Basin in the USA. The adsorption isotherms of these coals for three kinds of gases (CH_4, CO_2, N_2) are shown in Fig. 2 and Fig.1, respectively.

Table 1, 2 and 3 show the assumed condition of coal seam, initial condition of gases and adsorption constant of these coals for the gas flow simulation.

Fig. 1 Adsorption isotherm (sub-bituminous)

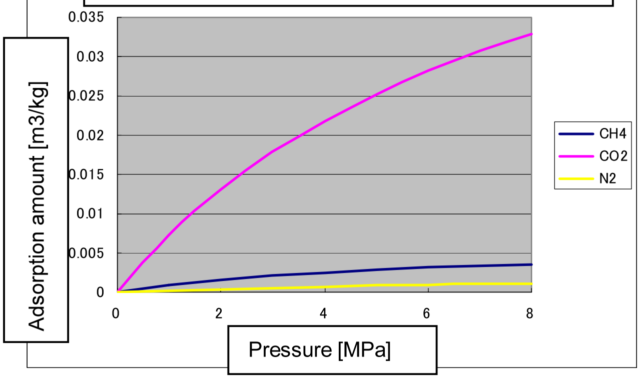


Fig.2 Adsorption isotherm (bituminous)

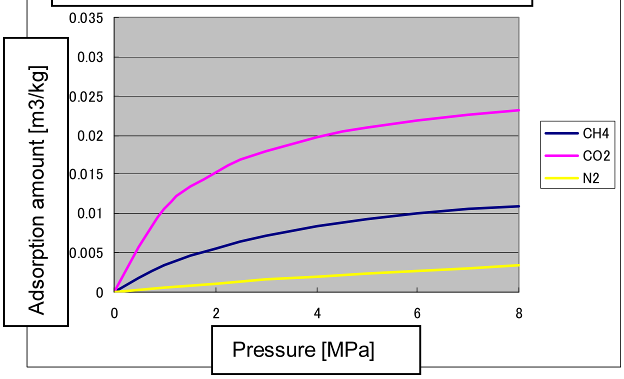


Table 1: Condition of coal seam

		sub-bituminous	bituminous
thickness	[m]	10	10
absolute permeability	[md]	50	5
porosity	[-]	0.01	0.01
effective compressibility	[kPa^{-1}]	1.45×10^{-7}	1.45×10^{-7}

Table 2: Initial condition

temperature		[C]	45
pressure		[MPa]	7.65
water saturation		[-]	0.9
gas concentration	CH_4	[-]	1
	CO_2	[-]	0
	N_2	[-]	0

Table 3: Langmuir parameters

			sub-bituminous	bituminous
ash content (by weiught)		[-]	0.029	0.112
moisture content (by weight)		[-]	0.239	0.016
Langmuir volume	CH_4	[m^3/kg]	0.0061	0.0161
	CO_2		0.0066	0.0279
	N_2		0.0023	0.0121
Langmuir pressure	CH_4	[MPa]	5.6534	3.7024
	CO_2		8.0806	1.6547
	N_2		9.2666	20.123

3. Simulation of Gas Production

3.1. Well model

The Enhanced Coalbed Methane Simulator, ECOMERS-UT [1,2] is used for the simulation. Well pattern is 5-spot pattern . 5x 5 grids are used for the calculation. Grid number was defined as shown Fig. 3. Grid (1,1) is injection well and grid (5,5) is production well.

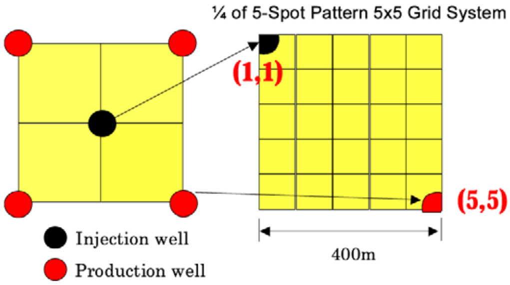


Fig. 3 Well model

3.2. Change of permeability

The change of permeability in the coal seam by injection of CO2 containing gas was calculated. The Palmer-Mansoori equation [3] expressing the relationship between adsorption amount and porosity (permeability) change was used. Fig. 4 shows the permeability change with time in primary production for sub-bituminous coal along the diagonal of grids. Slight increase of permeability is observed due to shrinkage caused by desorption. Fig. 5 shows the permeability change with time in pure CO2 injection for sub-bituminous coal. Dramatic permeability decrease near injection well is observed. However, the permeability around the production well is slightly increasing in the early stage of the injection.

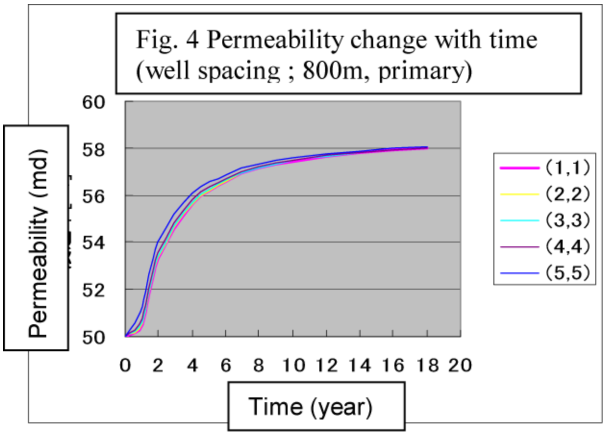


Fig. 4 Permeability change with time (well spacing ; 800m, primary)

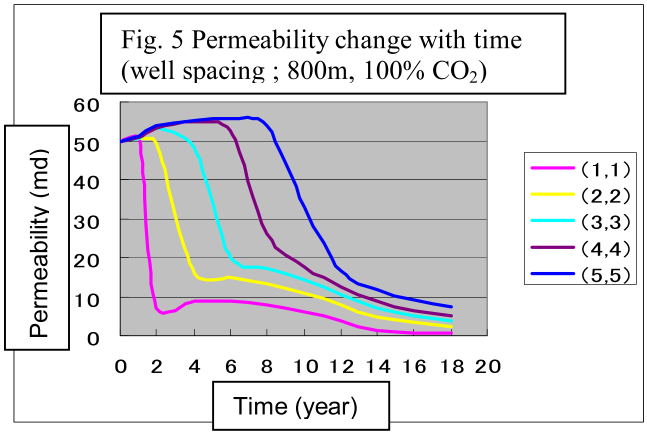


Fig. 5 Permeability change with time (well spacing ; 800m, 100% CO_2)

3.3. Gas production

Methane production with injection of different CO_2 concentration gas was calculated. The time of the commencement of injection is after the primary production of one year. Fig. 6 shows the results for sub-bituminous coal with 12,00m well spacing. Injection of low concentration CO_2 enhances the methane production. However, injection of pure CO_2 is not effective for the enhancement. It is caused by the permeability decease by CO_2 adsorption. Injected CO_2 is stored near injection well and does not move forward towards production well. Fig. 7 shows the CH_4 concentration produced from production well after injection. The decrease of CH_4 concentration is rapid in low CO_2 concentration gas. These results suggest that pure CO_2 injection in low rank coal seam exhibits low production enhancement and high CO_2 storage capacity.

Fig. 6 Enhanced CH_4 production

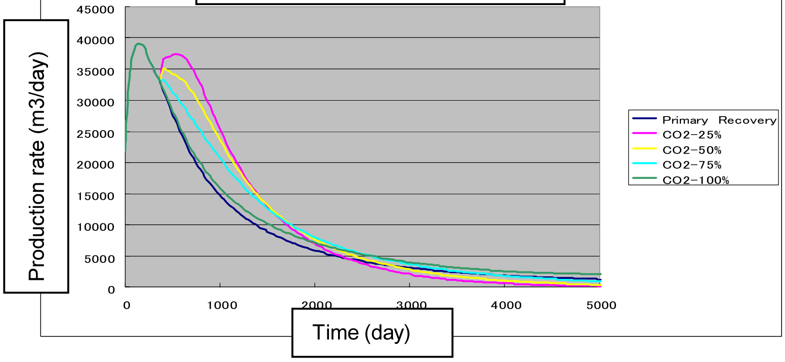
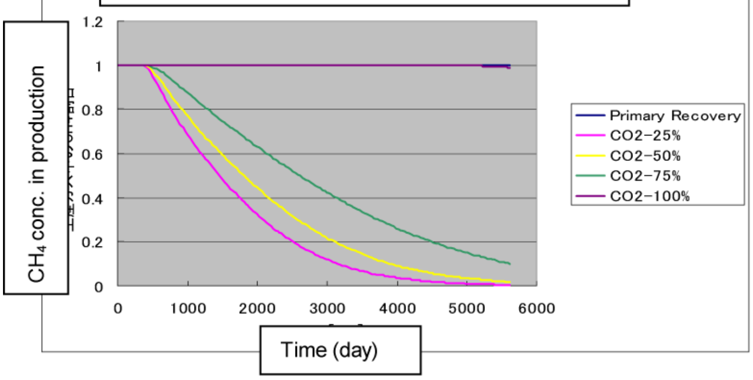


Fig. 7 CH_4 concentration in production gas



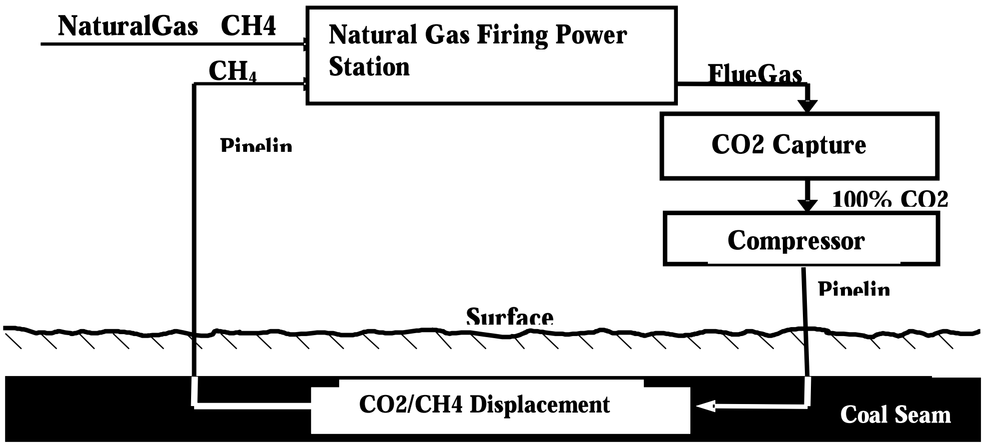
4. Economic Assessment

4.1. Condition of assessment

We assumed that CO_2 in the flue gas emitted from 1000MW natural gas firing power station is captured and stored in coal seam. This power station annually emits about 400 million tons CO_2. The hourly CO_2 injection rate was calculated to be 100,000sm^3/h from the annual injection volume and operating hours of the plant. Process conditions of CO_2 capture plant and transportation, injection conditions and base data for economic assessment are described as follows (Fig. 8);

1) CO_2 capture process: MEA
2) Compressor (5 stages)
3) Pipeline (50km from power station to injection site)
4) Injection and production facilities (injection pressure: 15MPa)
5) 81 injection wells and 100 production wells (7.2 km x 7.2 km: 5 spot pattern)
6) Project period: 18 years or time of breakthrough (90% CH_4 concentration)
7) CO_2 credit: US\$30/t-CO_2 (for base case)
8) CH_4 price: US\$4.44/MMBtu (for base case)

Fig. 8 Economic assessment model



5.2. Results

Table 4 and 5 show the NPV with different well spacing for sub-bituminous coal and bituminous coal, respectively. These results suggest that;

1) Primary production is more economical than ECBMR in the base case Carbon Credit.The feasibility of the CBM and ECBMR project strongly depends on the well spacing (number of wells) and CO_2 concentration of injection gas.
3) Optimum well spacing and CO_2 concentration is correlated. Optimum well spacing is about 1600m in primary production and 1000m in CO_2 injection for sub-bituminous coal.

Table 4: NPV for sub-bituminous coal [MMUS$]

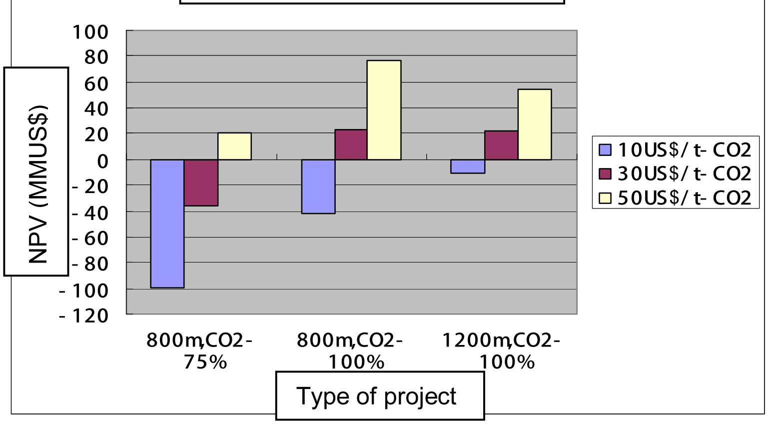
		Well spacing				
		400m	800m	1200m	1600m	2000m
Primary		-177.39	5.6	37.47	42.77	41.24
Enhanced (CO2 conc.)	25%	-555.33	-211.16	-93.72	-36.24	-13.01
	50%	-385.02	-128.93	-47	-13.02	-0.76
	75%	-300.49	-35.79	-5.87	6.02	9.13
	100%	-199.05	23.13	22.27	17.09	11.88

Table 5: NPV for bituminous coal [MMUS$]

		Well spacing				
		400m	800m	1200m	1600m	2000m
Primary		-46.12	11.89	1.98	-5.38	-9.04
Enhanced (CO2 conc.)	25%	-770.6	-136.82	-52.72	-40.23	-33.84
	50%	-353.26	-63.07	-30.63	-29.65	-28.06
	75%	-59.58	0.04	-12.89	-22.78	-27.38
	100%	-124.07	-43.45	-2.97	-20.91	-28.59

Fig. 9 shows the NPV in sensitivity analysis with regards to carbon credit for sub-bituminous coal. Carbon credit affects the NPV strongly in high concentration CO_2 injection.

Fig. 9 NPV with carbon credit



6. Conclusion

With a rather simple production model, the economic assessment of ECBMR project in low rank coal was made. The advantage of low rank coal in ECBMR is high CO2/CH4 adsorption ratio and high permeability relative to the bituminous coal. The disadvantage is severe swelling.

Economic assessment showed that the number of wells (well spacing), the CO_2 concentration and carbon credit are the most important factors determining the feasibility of the project.

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